NAIC-ID(RS)T-0619-95

NATIONAL AIR INTELLIGENCE CENTER

SUMMARY AND ANALYSIS OF U.S. ELECTROTHERMAL CHEMICAL GUN SUCCESSES

by

Cheng Daimo, Xu Zhongxin

Approved for public release: distribution unlimited

HUMAN TRANSLATION

NAIC-ID(RS)T-0619-95 8 March 1996

MICROFICHE NR: 96C000220

SUMMARY AND ANALYSIS OF U.S. ELECTROTHERMAL CHEMICAL GUN SUCCESSES

By: Cheng Daimo, Xu Zhongxin

English pages: 23

Source: Unknown.

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: NAIC/TASC/Richard A. Peden, Jr.
Approved for public release: distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE NATIONAL AIR INTELLIGENCE CENTER.	PREPARED BY: TRANSLATION SERVICES NATIONAL AIR INTELLIGENCE CENTER WPAFB, OHIO

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

ABSTRACT This report provides a summary of the status of U.S. electrothermal chemical propulsion. Systematic research points out that--with regard to areas associated with different combat missions--it is a vital design. The ones with the best prospects are theater missile defense, anti warship missile defense, and defense against indirect fire support with very long ranges. Results with regard to countering armor are not that clear. Besides that, research points out that it is necessary to consider reducing electric energy requirements (on the basis of more mature calculations done at the present time with regard to pulse power). At the same time, what is even more important is that methods relying on the use of electrical energy inputs to control combustion go through increases in chemical energy in order to raise performance. As a result, development work on propellants, cutting across broad fields in new forms of chemistry, is the main focal point of U.S. electrothermal chemical research work now. In the report, what is presented is that, as far as multiple types of propellants are concerned, there are clear increases in energy densities (as compared to solid propellents at the present time). It seems that the use of electric power to produce controlable plasma phases is compatible. Finally, the current status of U.S. electrothermal chemical plans, which is introduced in this report with regard to different combat task areas, clearly shows that the concept of electrothermal chemical propellants is in the process of going out of the laboratory, and, in conjunction with that, entering into the battlefield test and verification stage in relevent weapons systems of the next generation.

KEY TERMS Electrothermal chemistry Electrically strengthened systems Plasma Combustion speed

1 INTRODUCTION

The concept of electrothermal chemical (ETC) propulsion is a catagory of technology. It is capable of strengthening to a great extent ballistic performance (projectile gun muzzle velocities or kinetic energies) in order to satisfy the requirements of future military propulsion technology. Electrothermal chemical propulsion is a composite propulsion concept. It opts for the use of standard solid propellant gun hardware (for example, gun tube) technology, and, at the same time, makes use of two types of energy--electrical energy and chemical energy--in order to increase ballisitic performance. Because of this, electrothermal chemical propulsion technology is, at the present time, providing possibilities for raising ballistic performance of various types of field weapons platforms. In conjunction with this, it provides a foundation for deciding to make use of guns currently on hand in new combat mission areas (for example, theater missile defense (TMD)).

With a view to those possible advantages discussed above, in the last few years, a number of agencies of the U.S. Defense Department have already studied taking electrothermal chemical concepts and introducing them among the possibilities associated with weapons systems currently on hand or proposed for development. Special combat mission areas which have been studied include: (1) air defense (AD); (2) light armored vehicles (LAV); (3) antiarmor (AA); (4) indirect fire support (guns); and, (5) theater missile defense. The objective of this article is to generally describe a portion of the U.S. Defense Department's recent, current, and proposed development projects. In particular, this article discusses: (1) systematic (integrated) research as well as the influences produced in the two areas of project and electrothermal chemical technology research; (2) recent important technological successes; (3) the status of currently running projects as well as various proposed projects funded by the U.S. Defense Department in each of the combat mission areas discussed above.

2 SYSTEMATIC RESEARCH

At the present time, research work on 5 principal systems associated with electrothermal chemical propulsion is either already completed or in the process of being carried out. Among these, the U.S. Army has two. The U.S. Navy has three. /2 For a brief description of each research project, see the article below. Note: In the U.S., electrically enhanced coefficients (EEF) are used to act as a measurement of the electrical energy needed during electrothermal chemical combustion. Electrically enhanced coefficients are defined as the ratios between projectile gun muzzle kinetic energies and electrical energy inputed into rear gun chambers.

Research on High Velocity Launch--Theater Missile Defense Systems (HVL--TMD System Research)

As far as this already completed research is concerned, it was finished by the General Electric Company. This company is the primary contractor for the U.S. Army Space and Strategic Defense Command (USASSDC). The objectives of the research in question are: (1) to determine the suitability of high velocity launch technology for use in theater missile defense; (2) to develop requirements for high velocity launch weapons systems, and, in conjunction with that, synthesize and construct concepts associated with theater missile defense; (3) to set up a development plan for key high velocity launch--theater missile defense technologies; and, (4) to take high velocity launch weapons systems and weave them into GPALS and various types of different theater defense systems. Although system effectiveness (that is, lethality) is the first question considered in this study, various other factors, such as costs, also need to receive consideration. Results of studies on launcher sections point out that electrothermal chemical propulsion technology provides an effective method of deciding theater missile defense missions related to point defense. As far as two primary technology factors viewed as final results of this study are concerned, one is that there is a possibility--from electrothermal chemistry--to provide "soft" launch capabilities (Theater missile defense combat missions require low launch overloads on smart projectiles.). The other is that--making use of electrothermal chemical propulsion concepts--short and precise ignition times are clearly shown. Speaking in terms of the precise launch control required because of the situations associated with theater missile defense missions, the latter is key.

Studies by the U.S. Army Research Laboratory on Electrothermal Chemical Guns

The objectives of carrying out this research were: (1) to determine initial methods for deciding to make use of the two concepts--conventional solid propellants (SP) and electrothermal chemical propellants--to satisfy the requirements of air defense, light armored vehicle, antiarmor, indirect fire support weapon, as well as theater missile defense missions; and, (2) to calculate out the mass and volumes associated with the various subsystems of weapons as a whole (gun, breech block, counter recoil mechanism, rammer, pulse formation network, and so on). After that, comparisions were completed for mass, volume, and combat efficiency between the two--conventional solid propellant and electrothermal chemical propellant. Preliminary research results indicate that, in high velocity launch--theater missile defense studies, electrothermal chemical propellants are a very

attactive solution method with regard to theater missile defense missions. At the same time, in regard to light armored vehicle and antiarmor missions, they are still viable. With regard to indirect fire support missions, while solid propellants are put forward to reduce system loads (mass and volume), requirements of launch velocity and launch speed lead to both solid propellants and electrothermal chemical propellants being unsatisfactory in regard to air defense missions. However, it should be pointed out that air defense situations are based on "silent" projectiles. Moreover, range against indirect fire weapons is 50km. With regard to air defense, opting for the use of small caliber smart munitions, and, in conjunction with that, increasing range requirements with regard to indirect fire support weapons, it is then possible to alter research results. Finally, if electrothermal chemical propulsion is the solution method to provide viable weapons systems, then research work stresses the necessity of taking electrical power utilization and reducing it to a minimum (for example, current and estimated energy and power densities associated with electronic components).

U.S. Navy Studies on the Dimensions of Electrothermal Chemical Gun Pulse Formation Networks (PFN)

This research has already been carried out by the Navy Surface Weapons Center (NSWC) Carderock section. The objective is to determine the influences of dimensional areas associated with electrical enhancement coefficients in electrothermal chemical gun power systems on various Navy combat units. Studies have already been made of applications to electrothermal chemical 60mm close in weapons systems (CIWS) and 5 in electrothermal chemical guns. The results point out that, speaking in terms of CIWS applications, electrical enhancement systems increase from 1 to 10. Masses and volumes of electric power sources are reduced to 90% of the original structure. When application is made to 5 in guns, electrical enhancement coefficients increase from 2 to 10. The mass and volumes of the corresponding power systems are reduced to 80%. Besides basic dimension reductions, increasing electrical enhancement coefficients is also capable of being used in order to alter charging states associated with pulse formation networks so as to facilitate permiting increased flexibility in launch velocities. Finally, dimension reductions will give rise to electrical enhancement system enlargements. As a result, /3 it is possible to apply compromise methods in order to increase the reliability of pulse formation networks, raising their efficiency, and, in conjunction, lowering costs.

Comprehensive Research on the U.S. Navy Electrothermal Chemical Guns/DDG51

This study was completed by the David Talyor research center. Its object is to evaluate the overall effects of pulse

power systems on electrothermal chemical guns mounted on DDG51 (destroyer) class warships. In the same way as previous research, studies have been done of the two plans--for 60mm CIWS and 5 in guns. Research results indicate that, speaking in regard to rational weapons load characteristics, the application of pulse power weapons in navy units is not subject to power limitations on current ships, but is limited in capabilities to regulate power characteristics. Power sources acting as electrothermal chemical pulse loads are capable of, and, in conjunction with that, ought to be obtained from warship propulsion systems. The studies in question point out that this type of common use power system--at high ship speeds--has extremely small effects on warship performance. Finally, in the case of ships that are designed with volume restrictions on the warship as a whole--for example, DDG51--pulse power component heat treatment is still an important technological problem.

Technological Designs of Advanced U.S. Navy Gun Weapon Systems

At the present time, this research has just been completed by the U.S. Navy. The objective of the studies is to put forward and analyze multiuse weapons systems. These weapons systems are not only capable of satisfying the requirements of surface warships in the attack, they are also capable of satisfying them in the defense. The defensive missions discussed include countering warship missiles, countering warship aircraft, countering surface warships, coastal defense aircraft, as well as mines. Moreover, attack missions include surface fire support, offensive combat, as well as suppressing hostile air defense power. This research not only discusses the selection of launcher plans (for example, electrothermal chemical and liquid propellant systems). Moreover, it also discusses projectile, fire control, and cost questions. The results of the studies can be obtained before the end of the year.

Although research associated with the systems discussed above is concentrated in various different types of fields of warfare, among these studies, however, there are a few common research problems. These subjects are related to electrothermal chemical propulsion. For example, there are electrical energy requirements, smart projectiles, and soft launches. In electrothermal chemical propulsion technology, the subject with the mose striking influences is electrical energy requirements needing to be lowered to levels that are believed to be acceptable. This king of problem was just brought to a conclusion a few years ago.

If electrothermal chemistry turns into a feasible propulsion plan, and is applied to a majority of combat missions, then, in the U.S., electrical energy requirements being already reduced to a minimum comes to be seen as the key question at the present time. As was discussed above, electrical enhancement coefficients act as one measurement of the electrical power needed during electrothermal chemical combustion. Fig.1 clearly

shows one comprehensive research concept including electrical enhancement coefficients, pulse formation network system mass, volume, and costs。 This Fig. is made with reference to a 17MJ vehicle (gun muzzle kinetic energy) electrothermal chemical (capacitor pulse formation network) tank gun system completed by the General Dynamics company land systems section (GDLS) under a commission from the U.S. Army. In the Fig., it is pointed out that a quadratic curve relationship presents itself between

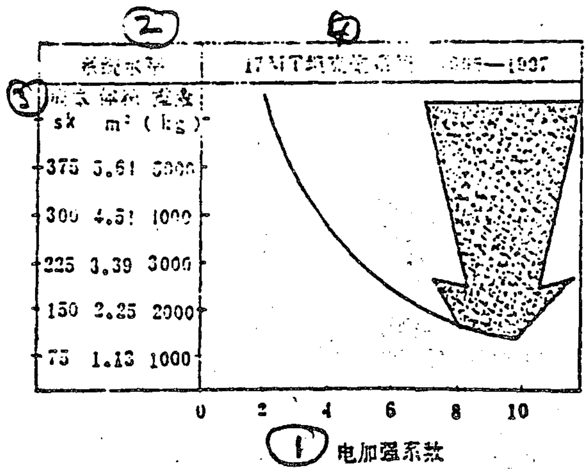

Fig.1 Relationships Between PFN System Mass, Volume, and Costs and EEF (Tank Gun)

Key: (1) Electrical Enhancement Coefficient (2) System Levels (3) Cost Volume Mass (4) 17MJ Tank (illegible)

electrical enhancement coefficients and a number of other parameters. This is the result of introducing launch speed /4 influences during calculations (graph lines should be linear for single launch combat situations). From the Fig., it is possible to see that, if pulse formation networks occupy 2m3 (in the M1A1/M1A2 tanks, it is believed that this is the largest volume that can be used), there is then a need for electrical enhancement coefficients with levels of 8 to 10。 What is worth paying attention to is that electrical enhancement coefficients of at least 10 are in line with the U.S. Navy dimension research results on electrothermal chemical gun/pulse formation networks that were discussed above。

3. TECHNOLOGICAL ACHIEVEMENTS

If one is thinking of raising ballistic performance, it is not for one to use increased gun efficiency to supply additional energy in order to attain this. It is simply a method taking a number of individual factors and combining them together in order to realize it. However, if electrothermal chemical guns are going through combustion gas motive processes in order to complete propulsion, then, it will be obvious that improving gun efficiency is not very possible. As a result, it is necessary to successfully realize the concepts of electrothermal chemistry, or one must rely on supplying high energies to the system. The objectives of high electrical enhancement coefficients which were discussed in sections above mean that increases in electrical energy must make use of chemical methods. Because of this, as far as propellant development is concerned, research is already being carried out at the present time by a great many U.S. electrothermal chemical research agencies. This is the key factor in successfully realizing electrothermal chemical propulsion concepts. As a result--speaking in terms of the U.S. today having the majority of electrothermal chemical technology results and this article--combining propellant developments and approriate cartridges into an integral whole is precisely the center of things at the present time. Needed propellant characteristics include high volume energy densities (>8 MJ/L), the capability for high load densities (>1.3g/cm3), medium flame temperatures (<3400k), and combustion control through electrical energy inputs. Besides this, they must satisfy requirements associated with low sensitivity munitions, safety, as well as the environment.

During the past few years, the U.S. Army, together with their contractors (FMC, GDLS, Olin Ordnance, and Princeton Combustion Research Laboratory (PCRL)), have already evaluated and, in terms of theory (through thermodynamics calculations and ballistics calculations), assessed over 1050 formulations. Among these, 30 formulations have already been manufactured. In conjunction with this, they have gone through sealed combustion chamber and gun firing tests (Note: The majority of the formulations were researched by the Olin Ordnance contractor. These studies belong to the U.S. Army Altemate electrothermal chemical propulsion project. However, the research results produced are capable of being used in all U.S. electrothermal chemistry circles.). The formulations studied covered a very wide range in chemistry. Very many of the formulations exceeded the ranges and physical states associated with traditional gun propellant materials (that is, solid, liquid, colloid, and so on, and so on). Fig.2 gives a general schematic description of a number of the ideas. It guides propellant assessment programs.

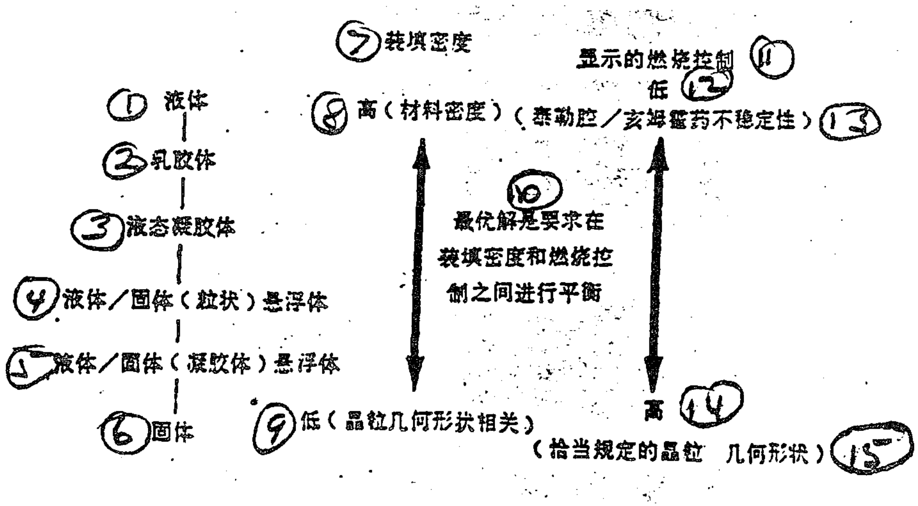

Fig.2 Propellant Selection

Key: (1) Liquid (2) Emulsoid (3) Liquid State Gel (4) Liquid/Solid (Granular) Suspension (5) Liquid/Solid (Gel) Suspension (6) Solid (7) Loading Density (8) High (Material Density) (9) Low (Correlated with Crystal Gain Geometrical Shapes) (10) The Best Solution Is to Require the Carrying Out of a Balancing Between Loading Densities and Combustion Control (11) Demonstrated Combustion Control (12) Low (13) (Tailor Cavity/Haimuhuo (Phonetic) Charge Instability) (14) High (15) (Properly Specified Crystal Gain [illegible] Geometrical Shapes)

Table 1 provides selected results with regard to a few types of fomulations. These formulations are already produced, and, in conjunction with that, tests have been made. In Table 1, when calculations are made of numerical values associated with various types of formulations, loading densities are taken to be material densities. Although doing this will skew things toward solid propellants, cases where they are estimated too high are still extremely small. /5

Table 1 Selected Electrothermal Chemical Propellant Results

1 推进剂型号	2 比能量* (J/g)	3 火焰温度* (K)	4 密度 (g/cm³)	5 体积能量密度* (MJ/L)	6 内弹道模拟动能* (MJ)
7 固体 (Olin)	1173	3356	1.65	7.61	16.7
7 固体 (ARDEC)	1220	3230	1.66	8.08	16.9
7 固体 (Olin/GDLS)	1241	3223	1.68	7.93	16.8
8 胶体 (Olin)	1070	3018	1.55	7.96	16.3
9 悬浮体 (FMC)	1131	3502	1.58	8.12	16.6
10 乳胶体 (PCRL)	1052	2893	1.45	7.17	16.0

* 不加电能 11

Key: (1) Propellant Type (2) Specific Energy (3) Flame Density (4) Density (5) Volume Energy Density (6) Interior Ballistics Simulated Kinetic Energy (7) Solid (8) Colloid (9) Suspension (10) Emulsoid (11) Electric Energy Not Added

The reason is that, at the present time, results in large amounts all carry with them a form in their entirety, a compressed form, as well as other properties of solid propellants. Besides this, volume energy densities or specific energies are traditionally seen as one measure of relevent propellant advantages. However, due to new chemical properties, it is possible to cause thermal chemical values (that is, specific heat ratios) to very, very greatly exceed the ranges associated with traditional solid propellants containing a lot of electrothermal chemical formulations in them. These thermal chemical values are capable of providing one imprecise indication of the capability of propellants to complete operations. The authors believe that a better measure for comparing propellant performance is interior ballistic simulation. The last column in Table 1 is simulation results for fixed bore pressures in 120mm guns (muzzle kinetic energies).

Besides high energy densities, with regard to other primary characteristics required in electrothermal chemical propellants, combustion control is carried out through electrical energy inputs. What is of particular interest is: (1) uniform ignition (in space and time); (2) control of the speed of rising and falling pressure (not "out of control" combustion); (3) ability to predict changed ballistic processes; and, (4) recognize whether or not plasma will alter the combustion speed of solid propellants.

Fig.3 and Fig.4 show results for ignition time delays and /6

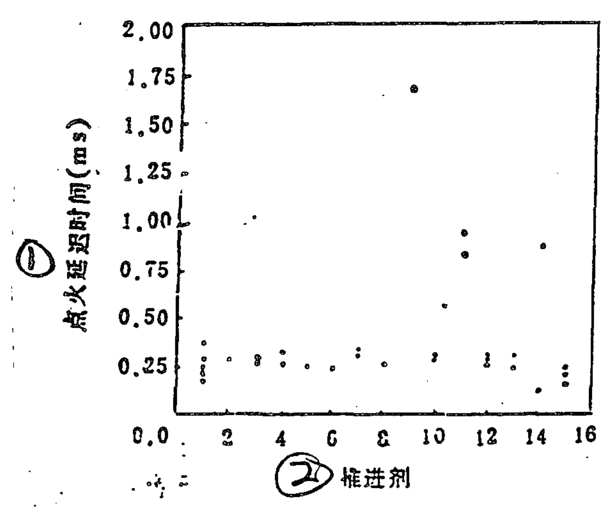

Fig.3 Ignition Delay Times

Key: (1) Ignition Delay Time (2) Propellant

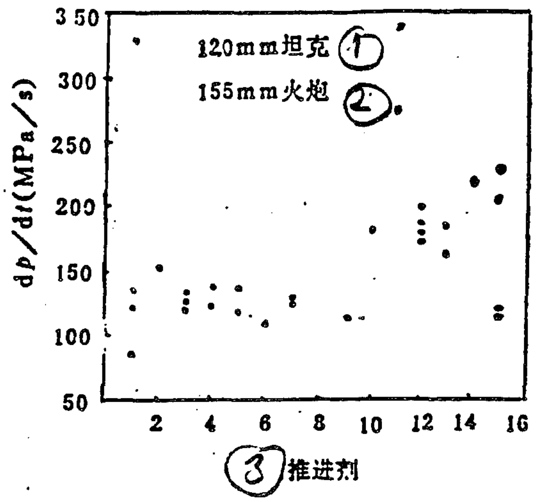

Fig.4 Measured Rates of Pressure Rise and Fall

Key: (1) Tank (2) Gun (3) Propellant

rates of pressure rise and fall. These results are gotten for those propellants discussed and studied above which have already been produced and tested (including liquids, solids, suspensions, and colloids). From Fig.3--with regard to propellants which have already been tested--it is possible to observe that electrothermal chemical ignition produced an ignition time delay which is extremely coincident. The value average is 0.35ms. It is, in fact, better than the 10 ~ 15 ms reached by conventional ignition time delays. Fig.4 points out that electrothermal chemical ignition--in the area of rates of pressure rise and fall (dp/dt)--will not lead to cases of "out of control" combustion as compared to conventional gun systems. This is at least the case with regard to propellants which have already been tested.

An electrothermal propellant design with prospects should have a capability to make use of a single propellant charge but also be able to make use of altered electrical input methods in order to change trajectories. This type of capability--applied within required ranges (artillery) or when firing multiple types of projectiles from the same artillery piece--is particularly important. Recently, the GDLS company--under a commission from the U.S. Army--has already proved that, opting for the use of a fixed charge structure, methods which go through altered electrical energy inputs are capable of predicting altered

trajectory processes with this type of capability. Fig.5 and Fig.6 show the status of bore pressures as a function of time changes as well as the corresponding power curves. The curves in the Fig.'s are done altering pressure change rates dp/dt ± 20% on a fixed base line (30mm). With regard to maximum bore pressure curves and bore pressure curve widths, similar results were verified in all cases.

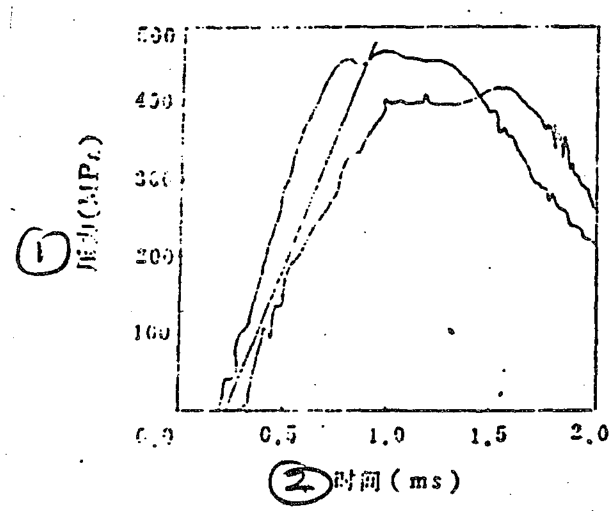

Fig.5 Curves for dp/dt Alterations of ± 20% (1) Pressure (2) Time

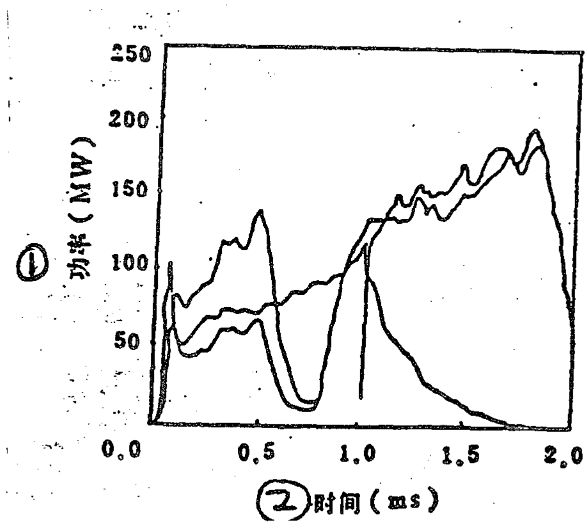

Fig.6 Power Curves

Key: (1) Power (2) Time

Although, in the ways discussed above, important progress has already been achieved in the areas of predicting altered ballistic processes and in actual predicted performance, in the majority of cases, however--in ballistic models--there is still a need for an appropriate level of empirical methods. This is particularly the case with regard to combustion gas formation rates (combustion speed) of propellants as associated with whether or not there is the appearance of plasma. As a result, before 1992, an important impetus in electrothermal chemical research appeared in nothing else than in these types of measurements of rates. Even with a lack of the appearance of plasma--in regard to formulations including liquid propellants--the measurement of combustion speeds is extremely difficult. However, with regard to measurements of combustion speeds associated with solid propellants, with or without the addition of plasma, relatively good success was achieved. Fig.7 and Fig.8 give comparisons of combustion speeds derived for M30 and M43 propellants with and without the addition of plasma. The data associated with Fig.7 was obtained from electrothermal chemical sealed combustion chamber tests. The data in Fig.8, however, was obtained by making use of reverse analysis of actual gun firings. Looking at the two figures, very small differences appear between combustion rates derived with and without the addition of plasma. This conclusion has already obtained further confirmation from the predictions of a great many successful models associated with solid propellant electrothermal test firings. In test firings, what propellants make use of are combustion speeds associated /7 with sealed combustion chambers without the addition of plasma.

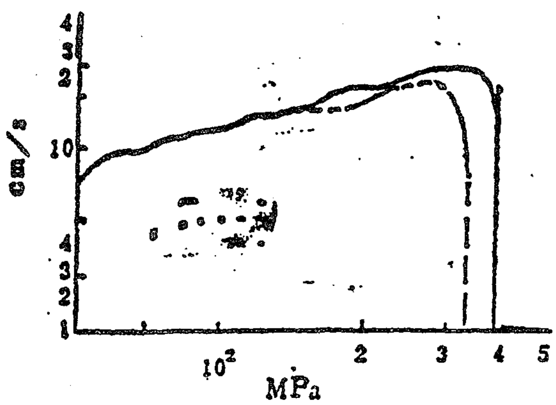

Fig.7 M30 Combustion Speeds With/Without Plasma

However, there are a number of indications that clearly show that plasma is capable of influencing solid propellant combustion speeds. These indications were discovered based on anomolous situations which appear when attempts are made to make comparisons between experimental solid propellant electrothermal chemical gun interior ballistic simulations and firing results. For results of this firing test (U.S. Navy 60mm electrothermal chemical gun test) see Fig.2. In the Fig., measured propellant

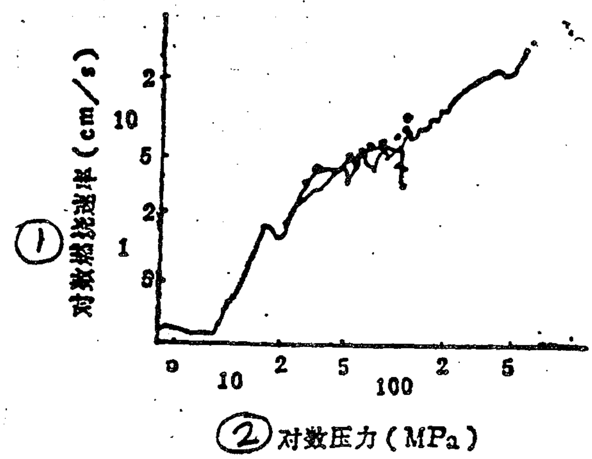

Fig.8 M43 Combustion Speeds With/Without Plasma

Key: (1) Logarithmic Combustion Speed (2) Logarithmic Pressure

combustion speeds are taken and increased to 30%. After that, one has test results without comparisons. A number of research workers assume that, if the ratio of local electric power and propellant surface area is large (>0.5GW/cm2) and the overall loading density is high (>0.95/cm3), then solid propellant combustion speeds will obviously increase. If applications of solid propellants are expanded in different conceptual areas of electrothermal chemistry, determining the influences of plasma on propellant combustion speeds is still an important field of research in technological terms.

Table 2 Influences of Increased Combustion Speeds on Ballisitic Performance

	燃烧速率系数	燃烧速率的增值 (cm/s)	变化率 (%)	速度 (m/s)	压力 (MPa)
实验	—	—	—	1040	400
内弹道模拟					
基准					
密闭燃烧室燃烧速率	0.03612	1.075	—	876	294
	0.04153	1.075	15	1002	348
	0.04537	1.075	27	1124	403
	0.04696	1.075	30	1154	420

Key: (1) Test (2) Datum (3) Sealed Combustion Chamber Combustion Speed (4) Combustion Speed Coefficient (5) Combustion Speed Increase Value (6) Rate of Change (7) Speed (8) Pressure (9)

4 STATUS OF PROJECTS IN COMBAT MISSION AREAS

Air Defense

The Balanced Technology Initiative (BTI)/U.S. Navy electrothermal gun demonstration project is the focal point of a U.S. concentration in electrothermal chemical projects associated with air defense. The objective of this project is to demonstrate the key technologies which are needed in order to develop rapid fire electrothermal gun weapons systems. This weapons system is capable of engaging targets, now and in the future, including antiship missiles and aircraft threats. Included among the technologies developed in the project are: (1) mutual compatiblities which should exist in all cases between CIWS structures currently existing as well as other restricting conditions on ships and rapid fire electrothermal chemistry guns, automatic rammers, charge structures, pulse formation networks and initial powers; (2) possession of lethality required in order to deal with command guided small caliber smart munitions associated with current and future threats; and, (3) tracking devices and fire control systems.

At the present time, guns and automatic rammer subsystems (manufactured by FMC) have already been completed, and, in conjunction with that, accepted by the government (all requirements have already been satisfied). As far as the design of thermoelectric chemical ammunition is concerned, it is carried out by G-DLS and FMC companies. The two designs both demonstrated that required capabilities of 1.1 to 1.2 km/s had been obtained. Small caliber smart ammunition is in the process of being developed by the General Electric company. It has already successfully passed full design review. In conjunction with this, such tests as sealed systems, wind tunnel, projectile casings, high overload, tracking, as well as lethality, and so on, have already been completely finished. At the present time, this project is slated to finish in fiscal 1994 with demonstration tests on dealing with flying targets.

Light Armored Vehicles

Work in this combat mission field is already primarily concentrated on electromagnetic launchers. The U.S. Army electronic equipment project agency and the U.S. Marine company are together in the midst of developing a standard caliber electromagnetic launcher (CCEML) in order to use in the next generation of amphibious armored assault vehicles.

Antiarmor

Due to maneuverability requirements (tank warfare), high firing speed and performance (gun muzzle kinetic energy),

antiarmor has been recognized as being the most complicated combat mission area for electrothermal chemistry launchers. Under a commission from the U.S. Army, both FMC and GDLS companies have done preliminary probes of application problems associated with tanks. Tank gun firing results from 30mm specifications only gave rise to relatively small performance improvements. The values exceeded conventional cases by 2.7%. However, 10 round repeatable continuous fire results all had increases. Results demonstrated that--for suspension propellants--standard speed deviations were 1.7%. For solid propellants, standard deviations were 0.31%. In the period from 1994 to 1995, if electrothermal chemical propellants are able to definitely satisfy antiarmor combat mission reqiurements, then, the U.S. Army itself and contractors will both take their research plans and make them definite.

Indirect Fire Support

If the performance of antiship missiles is already known, then, increasing the long distance firing ranges of weapons with respect to navy warhsips is then key (exceeding 100km). At the same time, the requirements of surface fire support missions expand firing ranges. In the light of the retirement from service of 16 in naval guns, the U.S. Navy, as a result, is in the midst of setting about to carry out efforts to strengthen the capabilities of its remaining 5 in guns. This project, that is the Navy/nuclear weapons defense agency (DNA) 5 in EATD project is a cooperative undertaking of the Navy and the nuclear weapons defense agency. It uses electrothermal chemical 5 in MK45 guns in order to provide fire support for targets with ranges reaching 60 nautical miles (approximately 100km). This project is built on the foundation of the BTI/Navy 60mm gun project (already discussed in the section on air defense). Moreover, recent electrothermal chemical projects by both the nuclear weapons defense agency and the U.S. Army completed phased tasks in all cases. Within the period of the nuclear weapons defense agency 5 in electrothermal chemical project, the Scientific Applications International company/FMC contractor group already achieved an approximately 18 MJ gun muzzle kinetic energy (25kg projectile, 1200 m/s speed)--the objective of this project. The S-Cubed/Maxwell Ltd. contracting group achieved somewhat lower results. In the U.S. Army EEF [illegible] ETC follow on projects, FMC and GDLS companies already demonstrated repeatable performance increases (gun muzzle kinetic energy) exceeding 15% (equivalent to the best conventional solid propellant /9 performance). Speed repeatabilities (10 rounds continuous fire) for suspension propellants had standard deviations of 0.99%. Standard deviations for solid propellant electrothermal chemical propulsion are 0.41%.

Theater Missile Defense

The recent Gulf War provided clear proof of the theater missile threat. As far as this type of missile--which can act as a political weapon as well as acting as a military weapon--is concerned, the proof of its effectiveness led to a sharp increase in offensive theater missiles all over the world. This sharply increasing trend and the development of chemical and nuclear technologies, which have been expanding right along, are connected to each other. Sharp increases in theater missiles provide for a great many nations low cost strategic capabilities. Otherwise very many nations will not have a capacity to support these. As a result, the U.S. Army space and strategic defense command (with the current nuclear weapons defense agencies) has already set about an ultra high speed electrothermal chemical launcher project in order to facilitate the setting up of vigorous defensive systems to fight back against this type of missile. When evaluating capabilities which are needed by theater missile defense weapons, two characteristics are key--transportability and cost effectiveness (high speed fire--theater missile defense system research). The possibility of regional conflicts in any area of the globe requires that defense systems be able to be transported easily and deployed fast. Due to the need for high hit and destruction capabilities, a requirement for multiple volley fire is presented. This then leads to any defensive missile system being extremely expensive. The reason is that defensive missiles which possess the required lethality require twice the costs of the attacking missiles which are hit and destroyed. As a result, the objective of the U.S. Army space and strategic defense command project is to develop a theater missile defense weapons system with good cost effectiveness and C-130 transportability. It makes use of one X frequency band interference measurement radar set in order to direct fire from one electrothermal chemical gun, hitting and destroying with ultra high speed guided artillery shells. This plan is a cooperative project with the government of Israel.

Initial tests were completed under plans from Israel's Soreq nuclear research center. With 60mm specification and solid propellant electrothermal chemical (SPETC) guns, they demonstrated the feasibility of ballistic control when plasma is added. Besides this, these tests proved that, using the same type of guns and making use of conventional propellants to cause gun muzzle kinetic energies to increase 22% is possible. (This is based on comparisons done with results obtained opting for the use of the same type of maximum combustion chamber pressures during conventional interior ballistic simulations and solid propellant electrothermal gun firings. Calculations also point out that it is possible to improve levels on the basis of expansion rates determined for actual guns during research.)

Work taking tests and expanding them, in accordance with proportions, to 105mm guns is currently in the process of being carried out. Initial results indicate that taking plasma and introducing it as a condition in order to realize methods of interior ballistic control seems to be easy to manage in guns

with large dimensions. Under conditions in which power is 1.4 GW, introducing overall plasma energies of 2.6 MJ, smooth pressure--time curves have already been achieved. Research into the influences of projectile mass on plasma increasing control of solid propellant ballisitic processes point out that, speaking in terms of projectile mass parameters, the sensitivities are not great. Looking from the point of view of theater missile defense, this is important. The reason is that theater missile defense artillery requires using very high charge to projectile mass ratios in order to carry out combat. As an example, tank guns are the same way. In initial test periods for 105mm guns, with no interior ballistic control problems, it was very easy to reach 2500 m/s speeds making use of 1.5 kg projectiles. At the present time, research work includes aggressively promoting increases in speed with regard to projecticle masses of interest associated with theater missile defense applications.

In the process of striving to convert laboratory research results to battlefield environments, a series of tests were begun in 1993 at Eglin Air Force Base. These tests included installing on the U.S. M110 self-propelled howitzer base plate a dual stroke 105mm Israeli tank gun (Fig.9 not clear). Fig.10 shows pressure-time curves. They were measured at the test station inside combustion chambers and gun bores. In the same way, curves were also supplied for power used in order to drive ballisitic processes for an early battlefield firing. In this test, using 497 MPa maximum bore pressure, gun muzzle speeds achieved were 1824 m/s. Applying interior ballistic simulations associated with IBHVG2 regulations, electrothermal chemical results were improved, and speeds of 1827 m/s were produced during maximum pressures of 497 MPa. During the tests that followed, equivalent secondary caliber theater missile defense projectiles have already been successfully launched from solid propellant electrothermal chemical guns. Peak value firing accelerations reached 62000 g overloads. Additional tests which were planned in this series of experiments included--under the control of fire control systems--firing tests of theater missile defense projectiles from solid fuel electrothermal chemical guns,

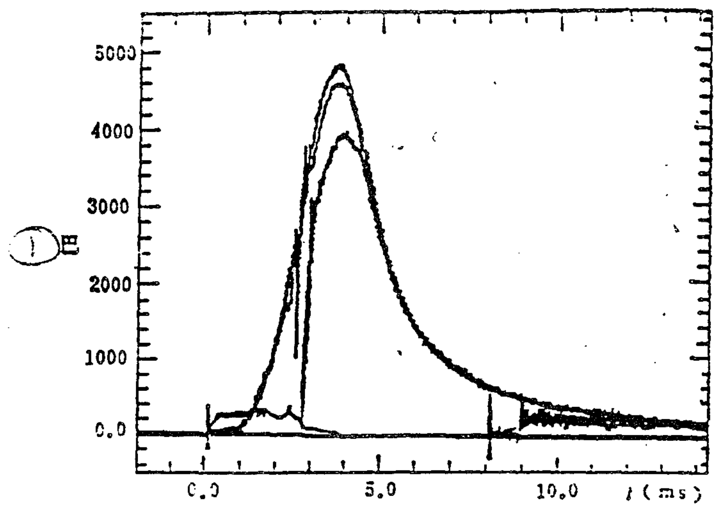

Fig.9 Pressure and Power Curves on M110 Base Plate (1) Bar

projectile tracking tests, as well as command verification tests associated with setting up projectile contact devices. Future tests--in situations associated with the raising of ballistic performance levels--are concentrated on flight tests associated with directing missiles to carry out actions.

REFERENCES

1 GDLS Decision Point 1 Briefing, Contract DAA15-92-C-0017, May 1993

2 Wren, G. P., W. F. Oberie, and S. L. Richardson, "Ballistic Analysis of Electrothermal-Chemical (ETC) Propellants", Technical Report U. S. Army Research Laboratory, Aberdeen Proving Ground, MD, in Press, June 1993.

3 Su, F. Proceedings of Second ETC Modeling Workshop, U. S. Army Research Laboratory, Aberdeen Proving Ground, MD, May 1993.

4 Anderson, R. D. and K. D. Fickie, "IBHVG2-A User's Guide", BRL-TR-2929, U. S. Army Research Laboratory, Aberdeen Proving Ground, MD, July 1987.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE
B085 DIA/RTS-2FI	1
C509 BALL0C509 BALLISTIC RES LAB	1
C510 R&T LABS/AVEADCOM	1
C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
Q592 FSTC	4
Q619 MSIC REDSTONE	1
Q008 NTIC	1
Q043 AFMIC-IS	1
E404 AEDC/DOF	1
E410 AFDTC/IN	1
E429 SD/IND	1
P005 DOE/ISA/DDI	1
1051 AFIT/LDE	1
P090 NSA/CDB	1

Microfiche Nbr: FTD96C000220
NAIC-ID(RS)T-0619-95